THE LOWER PALAEOZOIC ACRITARCHS *PRISCOGALEA* AND *CYMATIOGALEA*

by S. M. RASUL

ABSTRACT. The taxonomic status of the genera *Priscogalea* Deunff and *Cymatiogalea* Deunff is examined in the light of new evidence and the genera are emended. Six new species, two belonging to *Priscogalea* and four to *Cymatiogalea*, are described from the Shineton Shales (Tremadoc) of Shropshire, England.

IN 1961, Deunff erected *Priscogalea* for acritarchs with a large polar opening and random processes with or without polygonal areas. At the same time he erected *Cymatiogalea* also with a large polar opening, with or without polygonal areas but distinguished by membranes alone or membranes reinforced by processes. However, Deunff's *Priscogalea* included two forms: (1) one with processes developed at random all over the body surface with no polygonal areas delineated; *P. barbara* Deunff, the type species belongs to this group; (2) the other group includes forms having polygonal areas on the test surface with processes developed only along the boundaries of the polygonal fields; for example, *P. cuvillieri* Deunff (1961); *Priscogalea multarea* Deunff (1961), etc. Later Deunff (1964) emendated *Cymatiogalea* to include those forms of *Priscogalea* with polygonal areas, having polar openings varying from round to polygonal. Deunff then transferred the remaining species of *Priscogalea* (forms without polygonal areas and with processes developed at random) to the genus *Baltisphaeridium* Eisenack. Deunff's emendation of *Cymatiogalea* to allow for variable shapes of openings (round to polygonal) and also the delineation of polygonal areas either by crests (alae) or by processes alone or with processes and membranes developed along polygonal areas is justified in view of new evidence recorded in the works of Górka and by the present author. *Cymatiogalea stelligera* Górka and *C. cylindrata* sp. nov. show individuals with or without membranes.

MORPHOLOGY

(*a*) *Wall.* Test walls of *Priscogalea* and *Cymatiogalea* are single walled and of variable thickness. They look like *Baltisphaeridium* walls and are probably layered. Deunff (1961, 1964) and Górka (1967, 1969) did not comment on whether the test walls of *Priscogalea* and *Cymatiogalea* are single walled or double walled. Jux (1970), while examining finer structures in the walls of some Paleozoic acritarchs, concluded that wall structures of *Baltisphaeridium* and *Tasmanites* are similar, possessing growth lamelli, radial canals, etc. So *Priscogalea*, if comparable with *Baltisphaeridium*, may have the same sort of wall structure. The present author examined some thick-walled *Priscogalea* and *Cymatiogalea* species under the polarizing microscope in order to see if they polarize like the walls of *Tasmanites* or show any sign of radial structures; but no such results were recorded. This may be due to loss of mineral matter from the walls of *Priscogalea* or lack of magnification. Paris and Deunff (1970) recorded the

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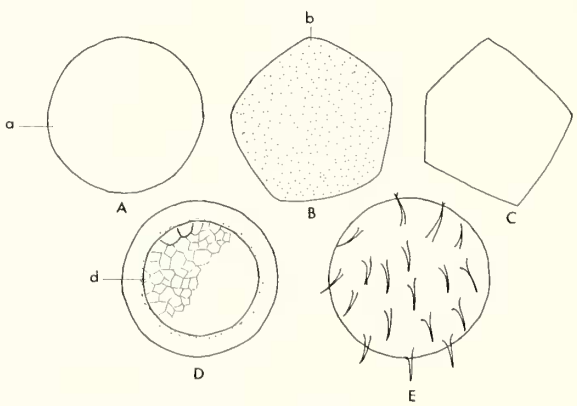
presence of two layers in *C. stelligera*: (1) a thinner outer membrane and (2) a thicker internal layer. It is difficult to observe the presence of such layers if they are closely pressed to each other. In all probability most of the test walls of *Priscogalea* and *Cymatiogalea* are single walled and are of a variable degree of thickness.

(*b*) *Openings*. The opening is usually variable in shape and size and possesses an operculum. The opening may be polygonal, subpolygonal, or circular in outline, e.g. *C. multarea*. However, a particular kind of opening may become predominant; for example circular openings frequently occur in *C. multarea*. The size of the opening is variable; for example the size of the opening may range from 34 to 91% of the body diameter in *C. cuvillieri*. In polar view, the size of an opening more or less corresponds to the size of its operculum, but in hemispherical view the size of the opening of the same species may appear larger than the corresponding size of its operculum. This may be due to lateral compression resulting in stretching out of the margin of the opening in hemispherical view. The opening may or may not be accompanied by a collar. The presence of a collar may be regarded as a development feature associated with thicker walled forms of *Priscogalea* and *Cymatiogalea*. But this association may not be a rigid one and varies within the species; for example *P. simplex* shows only a few specimens with the development of a collar. But a tendency to a well-developed collar may be a specific feature, as recorded in *C. cylindrata* in which most specimens show collars.

The operculum is always single, thin or thick walled, variable in shape according to the shapes of openings (i.e. circular, semicircular, or polygonal). It may or may not develop processes. The operculum does not show great variation in size; for example in *C. cuvillieri* the size of the operculum varies from 16 to 21 μ, whereas the test size varies from 23 to 37 μ. The operculum is commonly found missing (about 50%), sometimes loosely attached to the test near the margin of the opening (about 30%) or fallen inside the test (about 20%). The operculum when found inside the test is commonly associated with the test in the hemispherical view. The possible explanation of this phenomenon is the gaping of the margin of the opening in hemispherical

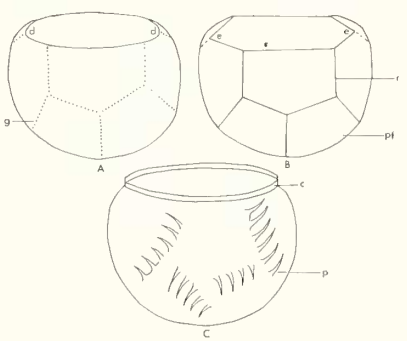


TEXT-FIG. 1. Nature of opercula (×1000 approx.). A, circular; *a*, smooth. B, polygono-spherical; *b*, granular. C, polygonal. D, thick walled; *d*, reticulate. E, operculum with processes.

view, thus facilitating the fall of the detached operculum inside the test. The operculum is rarely found *in situ*. Isolated opercula of variable shapes are recorded (text-fig. 1). The surface ornament of the operculum may vary from smooth, granular, microreticulate to striate, similar to surface ornament recorded in the test wall. The margin of the opening in most of the *Priscogalea* and *Cymatiogalea* appears distinctive as follows: (1) When the operculum is found *in situ*, the marginal zone appears 1–2 μ wide and the operculum can be easily distinguished from the polygonal areas of the test. (2) In a few species of *Priscogalea* and *Cymatiogalea* the margin of the opening is devoid of processes, e.g. *P. cortinula*, *C. cylindrata*. (3) In some species the margin of the opening is usually surrounded by a collar, e.g. *C. cylindrata*. (4) In a few species of *Cymatiogalea* processes and membranes are developed at one pole, whereas the opening is found at another, e.g. *C. bellicosa*. (5) In most of the species of *Priscogalea* and *Cymatiogalea* the margin of the opening is surrounded by processes which are similar to those developed at the junctions of polygonal fields. However, in those species in which the opening is usually circular in outline the margin of the opening is quite distinctive; no other plate in that specimen is circular in outline excepting the operculum, e.g. *C. multarea*. Specimens showing polygonal openings develop opercula which apparently look like any other polygonal plates of the test. But again, when the operculum is found *in situ* in such specimens, the marginal zone of the opening appears wide and is quite distinctive.

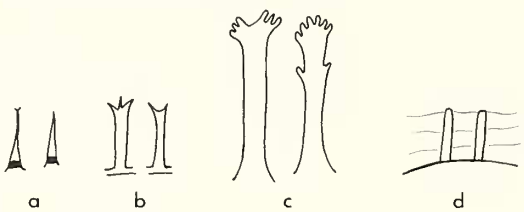
(*c*) *Surface ornament*. The test walls of *Priscogalea* and *Cymatiogalea* are smooth, granular, striate, or microreticulate.

(*d*) *Tabulation*. The body wall of *Cymatiogalea* is commonly divided into a number of polygonal areas by lines of granules, ridges, spines, or membranes reinforced by processes (text-fig. 2). The number and arrangement of these polygonal areas apparently show some similarity to the tabulation patterns observed in dinoflagellate cysts, but it is closer to *Pterosperma* (Boalch and Parke 1971). These tabulated *Cymatiogalea* do not show the presence of the cingulum usually noticeable in dinoflagellate cysts. They possess a large opening, angular to circular in outline. Ruptures and splits are occasionally observed along a sutural line near the margin of the opening. If polar is used to denote the opening then the polygonal areas are arranged equatorially in two or three rows below the polar opening and parallel to it. The tabulation pattern as recorded in *Cymatiogalea* can be expressed as: Operculum 1, Pre-equatorial row 4, Post-equatorial row 5, Basal area 1, abbreviated as follows: 1:4:5:1. The tabulation pattern in any species is variable, usually showing more than one pattern of tabulation, e.g. *C. velifera*. Some types of tabulation patterns are more frequently observed than others and could be the characteristic of a species, e.g. *C. multarea*.



TEXT-FIG. 2. Nature of division of polygonal fields and margin of opening (× 1000 approx.). In hemispherical view. A, polygonal fields divided by granules (g); *dd*, round margin of the opening. B, polygonal fields divided by ridges (r); *ee*, angular margin of the opening; pf, polygonal field. C, polygonal fields divided by processes (p); *c*, collar.

(*e*) *Processes, veils, etc.* (text-fig. 3). Processes (spines) recorded in *Priscogalea* and *Cymatiogalea* are mostly of the Baltisphaerid types. They are closed to the interior body cavity and thickened proximally, e.g. *P. simplex* and *C. trifida*. A few species of *Priscogalea* and *Cymatiogalea* show hollow processes communicating with the body cavity. Many species of *Priscogalea* and *Cymatiogalea* are distinguished by the nature of the processes and their tips. Processes may be short, long, simple, bifurcate, trifurcate, or multifurcate. The processes in *Priscogalea* develop at random from the surface of the test and the margins of the openings in most species are surrounded by processes, e.g. *P. simplex*. In a few species the margin lacks processes, i.e. *P. cortinula*. The processes in *Cymatiogalea* develop from the junctions of the polygonal areas. The margin of the opening is surrounded by processes, except for *C. cylindrata* sp. nov. In non-tabulated *Cymatiogalea*, like *C. bellicosa*, the membranes or thin veils are stretched between processes. In tabulated *Cymatiogalea* these veils develop at the junctions of the polygonal areas linking the processes. They appear transparent and are thinner walled than the process wall.



TEXT-FIG. 3. Types of processes and membranes (×1000 approx.). *a*, processes with thickened and constricted bases (baltisphaerid type). *b*, processes not communicating with the body cavity. *c*, hollow processes communicating with the body cavity. *d*, processes interlinked by membranes.

(*f*) *Clusters*. Aggregates of closely packed specimens of one species are recorded, containing three to more than 100 individuals per cluster, which are arranged in rows or chainlike patterns. The outline of these clusters is usually circular or ellipsoidal, and they are generally thickened in the middle, although a few clusters have an irregular outline. The former (uncompressed) shapes of these clusters are difficult to ascertain; but it is evident that the individuals of the clusters were associated with each other at different planes. The compact nature of these clusters and the association of a large number of individuals in some clusters suggest the formation of these before fossilization, rather than chance aggregation of the individuals during the maceration technique. Size variation in a cluster is smaller than that in the general population. The average size within one cluster may be slightly different from the average size in another. Clusters are not usually enclosed by any veil, sac, or organic tissue.

COMPARISONS

(*a*) *With dinoflagellates*: *Cymatiogalea* can be compared with tabulated dinoflagellate cysts in the following characters: (1) The presence of an opening formed by the loss of a single plate. (2) An arrangement of polygonal areas in more or less

parallel rows. (3) Splits observed along the margin of the opening appear to be opening sutures. This kind of split is common in dinoflagellates. However, there are important differences when compared with a typical tabulated dinoflagellate cyst: (1) No cingulum or bare zone on the test wall reflecting the presence of a cingulum is observed in *Cymatiogalea*. (2) The opening in *Cymatiogalea* is variable in shape from polygonal to circular in a single species. In dinoflagellates, it is usually more or less fixed in shape. (3) The tabulation pattern in *Cymatiogalea* cannot be stated on the system that is used for dinoflagellates. (4) A single species belonging to *Cymatiogalea* usually shows more than one kind of tabulation. In dinoflagellates, it is very constant in a species. (5) The test is usually single walled, of variable thickness. It cannot be said with certainty whether some forms do possess a double wall or not. In dinoflagellates, the test is usually double walled. Jux (1971*a*) studied the dinoflagellates and stated that the test wall material in dinoflagellates is usually fibrous in nature, more compact and homogeneous towards the body wall, and less compact and loose towards the process walls.

(*b*) *With Pterosperma* (*Prasinophyceae*): *Cymatiogalea* appears closer to living forms of the genus *Pterosperma* and especially to *Pterosperma nationalis* in respect of its tabulation pattern. In *Pterosperma* the wall is divided into polygons by narrow to deep partitions called alae, where combinations of between 3- to 6-sided polygonal areas occur. The individuals do not always give rise to the same pattern of tabulation as the parent form from which they developed. In *P. nationalis* the tabulation pattern on the wall can be all 3-sided, all 4-sided, 3- and 4-sided, or 4- and 5-sided: all 4s and the 3s and 4s being the most commonly occurring types. In *Cymatiogalea*, individuals of a species show several tabulation patterns out of which one or two types are more commonly occurring. For example, *C. multarea* shows the following tabulation patterns: 1:6:6:0; 1:6:5:0; 1:6:5:1; 1:5:5:1; 1:5:1:0; out of which 1:6:6:0 and 1:6:5:0 are more common. The opening in *Pterosperma* differs from that of *Cymatiogalea* in possessing pore canals scattered over the test wall.

CLASSIFICATION

Priscogalea belongs to the subgroup Acanthomorphitae (Downie, Evitt, and Sarjeant 1963). Eisenack (1969) erected a new botanical family Baltisphaeridiaceae to include several acanthomorph genera including *Baltisphaeridium*. It is difficult to say whether *Priscogalea* can be included in the Baltisphaeridiaceae, since nothing is known about the wall structure of *Priscogalea*. Jux (1971*b*) examined the wall structure of *Baltisphaeridium*, *Peteinosphaeridium*, and *Goniosphaeridium* and found them to be similar. All these genera are included in the family Baltisphaeridiaceae (Eisenack 1969). However, *Priscogalea* in general possesses most of the characters of the family Baltisphaeridiaceae. Most of the processes of the *Priscogalea* are of Baltisphaerid type and the test wall is thick. So, *Priscogalea*, if comparable with *Baltisphaeridium* in respect of the processes, may reveal the same sort of wall structure as that of *Baltisphaeridium*; until the wall structure is known, the question of the inclusion of *Priscogalea* in the family Baltisphaeridiaceae is rather uncertain.

Cymatiogalea belongs to the subgroup Herkomorphitae (Downie, Evitt, and Sarjeant 1963). The genus *Cymatiosphaera* also belongs to this subgroup. Mädler

(1963) created the family Cymatiosphaeraceae which is similar to the family Dictyosphaeriaceae created by Eisenack (1969). Boalch and Parke (1971) commented that *Pterosperma* is closely comparable with *Cymatiosphaera*. *Cymatiogalea* appears close to *Pterosperma* only with respect to its tabulation pattern to some extent. However, the question of the inclusion of *Cymatiogalea* in a family is uncertain.

RELATIONS WITH OTHER GENERA

Priscogalea can be distinguished from *Baltisphaeridium* (Eisenack 1958*a*, 1969) by its large, omnipresent, circular to polygonal opening with an operculum. Although most of the processes of *Priscogalea* are of Baltisphaerid type, some are hollow, communicating with the body cavity. The processes of *Priscogalea* are variable from simple to bifurcate or multifurcate. *Priscogalea* shows smaller size-range of its test than *Baltisphaeridium*. Eisenack (1969) restricts *Baltisphaeridium* to include principally forms with predominantly unbranched processes with processes closed at their proximal end. Small cyclopyles are occasionally recorded in *Baltisphaeridium* (sensu stricto). *Priscogalea* resembles *Cymbosphaeridium* Lister in possessing a large polygonal opening, but differs in being single walled, non-tabulated, having numerous processes. *Cymbosphaeridium* possess a double-walled test with restricted number (12–18) of plate-centred processes showing tabulation pattern like dinoflagellates. *Peteinosphaeridium* differs from *Priscogalea* in possessing triangular, winged processes and lacking a large polygonal opening.

STRATIGRAPHICAL DISTRIBUTION

Priscogalea appears first in the Upper Cambrian of Belgium (*P. simplex*; Vanguestaine 1967), then reaches its acme in the Tremadoc, where it is represented by several species, some with wide geographical extent, e.g. *P. simplex*. Then it declines to fewer species and ranges up to the Arenig (*P. striatula* Vavrdová and *P.* cf. *simplex* Lister *et al.*). Martin (1968) recorded *P. striatula* from the Tremadoc to the Ludlow in Belgium. However, the possibility that the Lower Ludlow form is reworked material from the Tremadoc cannot be ruled out. *Priscogalea* is not usually recorded above the Arenig from other areas.

Cymatiogalea appears first in the Upper Cambrian. Its acme was in the Tremadoc, where a good number of species of wide geographical range are recorded, e.g. *C. multarea* and *C. bellicosa*. *Cymatiogalea* is represented by a few species after Tremadoc and ranges up to Llanvirn, e.g. *C. cathaerine* Paris and Deunff (1970). Martin, Michot, and Vanguestaine (1970) recorded the presence of *C. cuvillieri* (Deunff) in the Caradoc of Belgium; again, the possibility of its being reworked cannot be ruled out, since it is very badly preserved.

Thus *Priscogalea* and *Cymatiogalea* are useful genera of Upper Cambrian and Arenig acritarchs. *Cymatiogalea* is closely comparable with the recent genus *Pterosperma* in its tabulation pattern.

SYSTEMATIC PALAEONTOLOGY

All the material described in this paper is in the collections of the Department of Geology (Micropalaeontology laboratory), the University of Sheffield; instrument settings of Vickers microscope No. 158143.

Genus PRISCOGALEA Deunff emend.

Type species. Priscogalea barbara Deunff 1961.

Emended diagnosis. Body spherical to hemispherical in outline; furnished with a large, circular to polygonal opening. Margin of the opening is usually decorated, rarely undecorated; may or may not possess a collar. Operculum with or without processes, consisting of a single plate, may remain attached, fallen inside the test, or usually missing. Test wall is of variable thickness, developing processes at random, single or branched mostly of *Baltisphaeridium* type, occasionally hollow.

Remarks. Deunff's diagnosis is emended to include the variability in the shape of the opening, with or without the collar and the nature of the processes.

Priscogalea fimbria sp. nov.

Plate 3, figs. 1 and 2

Holotype. Slide S6/1; ref. 431243. Bullhill Brook, Evenwood, Shropshire; Shumardia Pusilla Zone.

Diagnosis. Spherical to hemispherical body with thick processes of *Baltisphaeridium* type, most of which are divided into delicate filamentous threads near their distal ends. Wall thick, granular; opening usually circular, rarely polygonal. Sometimes distal branches of processes are found broken.

Dimensions. Body diameter: 35–45 μ; size of opening: 54–96% of body diameter; size of operculum: 20–23·6 μ; length of processes: 18–34% of body diameter; thickness of processes: 2–2·5 μ; holotype: body diameter 44 μ; size of opening: 77% of body diameter; size of operculum: 23·6 μ; length of processes: 18–22% of body diameter.

Remarks. Priscogalea fimbria sp. nov. can be distinguished from *Priscogalea distincta* sp. nov. by its relatively thicker, larger processes having filamentous tips, granular test wall, and somewhat larger size range of the body. *P. simplex* Deunff differs in having numerous slender processes with simple to bifurcate tips.

Priscogalea simplex Deunff emend.

Plate 3, figs. 3, 4, 5, 6

non 1950 *Archaeletes spectatisinus* Naumova, p. 189, pl. v, figs. 8–9.
1959? *Archeohystrichosphaeridium diplorum* Timofeyev, p. 34, tab. III, fig. 11.
1961 *Priscogalea simplex* Deunff, p. 41, pl. 1, fig. 9.
non 1962 *Baltisphaeridium simplex* Stockmans and Willière, p. 58, pl. 1, figs. 23, 24, text-fig. 15.
1964 *Baltisphaeridium simplex* (Deunff); Deunff, p. 122, pl. 1, fig. 14.
1964 *Baltisphaeridium spectatisinus* (Naumova); Deunff, p. 122, pl. 1, fig. 12.

Emended diagnosis. Body spherical to hemispherical in outline, smooth with numerous closely spaced short and simple processes, which sometimes distally develop small bifurcate terminations. Opening may or may not develop a collar.

Dimensions. Body diameter: 25–43 μ; size of opening: 43–85% of body diameter; size of operculum: 14–21 μ; length of processes: 11–23% of body diameter; size range of specimens in a cluster: 24·5–30 μ.

Description. Operculum variable in shape; test wall thick and smooth. Some processes are sparsely acicular. Clusters are recorded. On the basis of variability of processes, two varieties of this species can be recognized. *Forma 1.* Forms usually having simple processes with a few bifurcated tips. *Forma 2.* Forms usually having bifurcated processes, some of which are sparsely acicular, along with a few simple processes. Gradations exist between these two forms.

Remarks. Deunff 1961 described *P. simplex* having a body diameter of 25 μ, with short, simple processes about 5 μ in length and operculum 12–15 μ. The author recorded variations in the nature of the process tips and wider size range of the body in *P. simplex* emend.

In 1964, Deunff recorded (photograph only) a single specimen and designated it as *Baltisphaeridium* (*Archaeletes*) *spectatisinus* nov. comb. This specimen appears to have numerous short spines, mostly bifurcated, with a polar aperture about 13 μ surrounded by a collar; the body diameter is about 30 μ. This specimen corresponds to *Forma 2* of *P. simplex* emend. *Archaeletes spectatisinus* Naumova 1950 differs from *P. simplex* emend. in possessing fewer and longer processes and larger size of the body. Deunff (1964) transferred *P. simplex* to the genus *Baltisphaeridium* as *Baltisphaeridium simplex* comb. nov. without knowledge that *B. simplex* (non *Priscogalea simplex* Deunff) was previously described as a new species by Stockmans and Willière (1962) to represent a Devonian species belonging to the genus *Baltisphaeridium*. *Archaeohystrichosphaeridium diplorum* Timofeyev (1959), an invalid species (type species not designated by Timofeyev), appears similar to *P. simplex* in respect of its opening, nature of processes, but possesses larger size range of body: 35–45 μ.

P. simplex emend. differs from the type species, *P. barbara* in possessing numerous, shorter processes, simple to bifurcate, developed along the margin of the opening as well as on the test surface. In *P. barbara*, the margin of the opening is decorated by bifurcated processes, whereas the body surface is furnished with simple processes about 7–16 μ long. *P. timofeevi* Deunff differs from *P. simplex* in possessing larger processes (24–26% of the test diameter).

Occurrence. The Tremadoc of England and also the Sahara (Deunff 1961, 1964).

EXPLANATION OF PLATE 3

Figs. 1 and 2. *Priscogalea fimbria* sp. nov. 1, holotype, in hemispherical view. ×1000 approx. 2, specimen in polar view. ×1000 approx. Figs. 3, 4, 5, and 6. *Priscogalea simplex* Deunff. 3, 4, specimens in hemispherical view showing opercula falling apart. ×1000 approx. 5, stereoscan fig. in polar view clearly showing the opening. ×2000 approx. 6, cluster of several specimens. ×650 approx.

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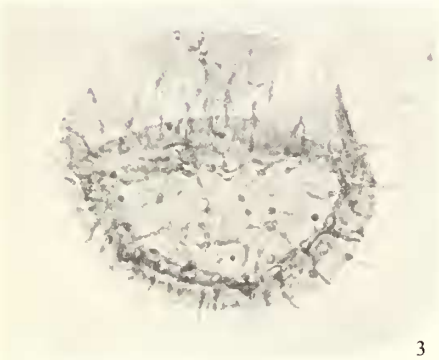

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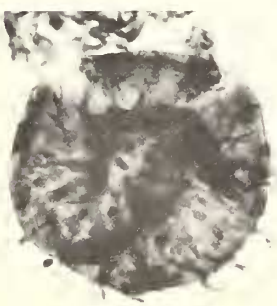

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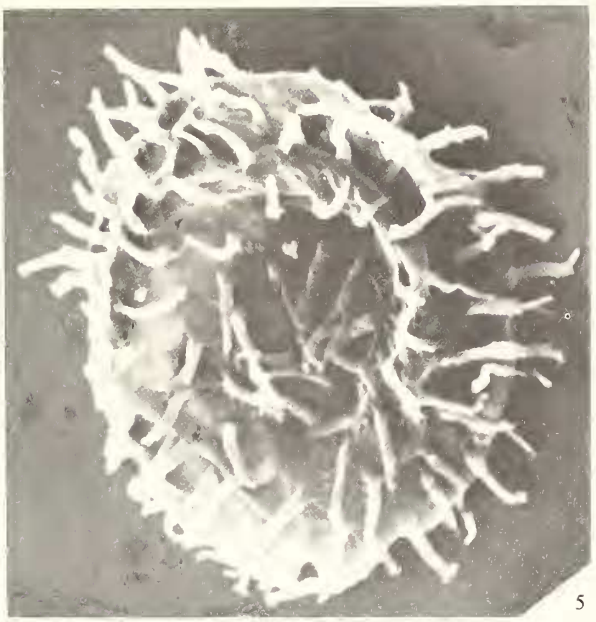

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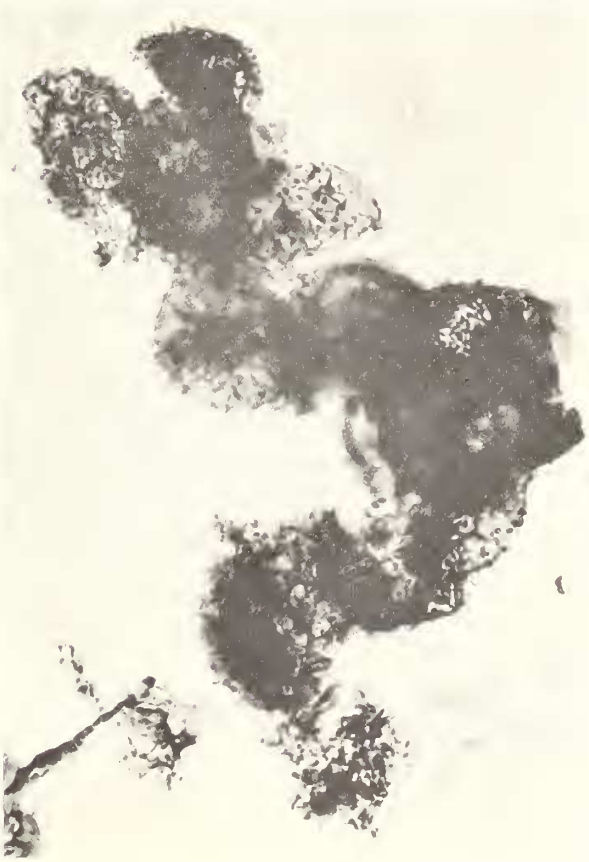

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RASUL, Tremadocian acritarchs

Priscogalea distincta sp. nov.

Plate 4, fig. 1; Plate 7, fig. 3

Holotype. Slide B5/1; ref. 3851237. River Severn, near Cressage bridge, Shropshire; Brachiopod Beds.

Diagnosis. Spherical to hemispherical body possessing acicular, tapering processes (usually forty in optical section), with multifurcate tips; test wall striate; opening usually polygonal. Processes are solid, thicker at their bases, and taper towards their distal ends where they usually multifurcate; sometimes a few forked or simple processes may also be present. Test wall is finely striate. These striae appear to radiate from the bases of the processes.

Dimensions. Body diameter: 28–38 μ; size of opening: 35–81% of body diameter; length of processes: 7–22% of body diameter; operculum: 14–21 μ; spacing of processes: 2–4 μ; holotype: body diameter 33 μ; size of opening: 75% of body diameter; size of operculum: 21 μ; length of processes: 19% of body diameter.

Remarks. *P. distincta* can be distinguished from *P. simplex* by its relatively thicker, multifurcate processes and striate test wall. *P. cortinula* differs in having fewer and bifurcate processes.

Priscogalea cortinula Deunff 1961

Plate 4, fig. 2; Plate 7, fig. 4

1961 *Priscogalea cortinula* Deunff, p. 41, pl. 1, fig. 8.
1964 *Baltisphaeridium cortinula* (Deunff); Deunff, p. 12, pl. 1, fig. 10.
1967 *Baltisphaeridium cortinula* (Deunff); Combaz, pl. III, fig. 86.

Description. Body spherical to hemispherical in outline with thick processes, often bifurcated at their extremities. The margin of the opening is devoid of processes.

Dimensions. Body diameter: 25–40 μ; length of the processes: 10–24% of body diameter.

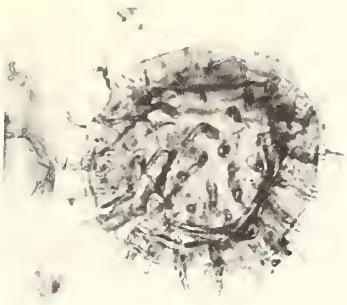
Remarks. *P. cortinula* differs from *P. simplex* emend. in having fewer and thicker processes and lacking marginal processes. *P. timofeevi* differs from *P. cortinula* in having larger processes which are simple to bifurcate. ?*Archaeolystrichosphaeridium bifurcatum* Timofeyev possesses larger processes.

Occurrence. The Tremadoc of England and the Sahara (Deunff 1961, 1964; Combaz 1967).

EXPLANATION OF PLATE 4

All figures approximately × 1000 unless otherwise stated.

Fig. 1. *Priscogalea distincta* sp. nov., holotype, in hemispherical view. Fig. 2. *Priscogalea cortinula* Deunff; operculum coming off. Fig. 3. *Cymatiogalea membranispina* Deunff. In hemispherical view from which operculum missing. Figs. 4 and 5. *Cymatiogalea velifera* (Downie). 4, specimen showing tabulation. 5, cluster of several specimens. × 650 approx. Fig. 6. *Cymatiogalea bellicosa* Deunff. Fig. 7. *Cymatiogalea multarea* (Deunff). Fig. 8. A cluster of *Cymatiogalea membranispina* Deunff. × 650 approx.



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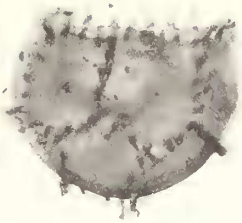

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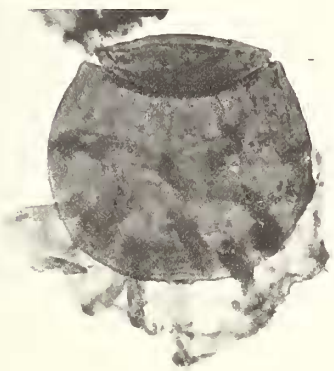

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RASUL, Tremadocian acritarchs

Genus CYMATIOGALEA Deunff emend.

Type species. Cymatiogalea margaritata Deunff 1961.

Emended diagnosis. Body spherical to hemispherical in outline usually furnished with a large circular to polygonal opening; operculum may remain attached, fallen inside the test or missing. The test surface is divided into polygonal areas by linear arrangement of granules, ridges, processes, or membranes. The margin of the opening may or may not be accompanied by a collar. Polygonal areas exhibit some sort of a tabulation pattern, usually observable.

Remarks. Cymatiogalea is emended in view of the new evidence recorded (i.e. the tabulation patterns). *Priscogalea* emend. is distinguished from *Cymatiogalea* emend. in lacking membranes, polygonal fields on the test surface, and developing processes at random all over the test surface.

Cymatiogalea velifera (Downie 1968)

Plate 4, figs. 4 and 5

1958 *Hystrichosphaeridium veliferum* Downie, p. 340, pl. 17, fig. 2, text-figs. 4*c* and 4*e*.
1964 *Baltisphaeridium veliferum* (Downie); Downie and Sargeant, p. 168.
1968 *Cymatiogalea velifera* (Downie); Martin, p. 133, pl. 1, figs. 8 and 9.

Description. Body spherical to hemispherical in outline; wall thick, infrareticulate. Polygonal areas on the test wall are marked by low sutural ridges along which processes and membranes occur. Splits along sutural lines are commonly observed. Processes are slender, mostly bifurcate or trifurcate near tips; thin veils with horizontal striations are stretched between the processes from proximal to distal ends.

The types of tabulation pattern are as follows, with percentages recorded: ,1:5:2:0 (30%); ,1:4:1:0 (30%); ,1:4:2:0 (30%); ,1:4:3:0 (10%). The clusters possess size ranges of test varying from 25·5 to 33 μ, 26·5 to 34 μ, and 25 to 30 μ.

Dimensions. Body diameter: 25–35 μ; size of opening: 50–95% of body diameter; size of operculum: 12–20·8 μ; length of processes and veils: 25–37% of body diameter; thickness of body wall: 0·5–1·5 μ.

Remarks. C. margaritata, the type species differs from *C. velifera* in having a larger body size (40 μ) and pillar-like processes and membranes on the test wall and in developing special cylindrical processes interlinked by membranes bordering the larger opening.

Occurrence. The Tremadoc of England and also Belgium (Martin 1968).

Cymatiogalea membranispina Deunff 1961

Plate 4, figs. 3 and 8; Plate 7, fig. 5

1961 *Cymatiogalea membranispina* Deunff, p. 42, pl. 1, fig. 6.
1964 *Cymatiogalea membranispina* (Deunff); Deunff, p. 121, pl. 1, fig. 9, pl. 1, fig. 18.

Description. Body spherical to hemispherical in outline. Wall smooth, divided into polygonal fields either by low sutural ridges or crests along which thin membranes develop supported by pillar-like processes. Opening is usually subpolygonal, rarely round.

Processes are usually slender, pillar-like with round tips. Sometimes they grade into swollen, club-shaped tips, rarely forked; thin veils unite the processes from their bases up to the tips. Clusters are recorded.

The tabulation pattern is variable. The following types are recorded: ,1:4:3:0 (50%); ,1:5:5:0 (40%); ,1:5:2:0 and ,1:6:4:1 are rare.

Dimensions. Body diameter: 24–45 μ; size of opening: 50–85% of body diameter; size of operculum: 15–22 μ; body wall: 0·5–2·5 μ thick; length of processes and veils: 12–30% of body diameter.

Remarks. C. membranispina differs from *C. velifera* in possessing numerous simple pillar-like processes supporting the membrane.

Occurrence. The Tremadoc of England and also the Sahara (Deunff 1961, 1964).

Cymatiogalea bellicosa Deunff 1961

Plate 4, fig. 6

1961 *Cymatiogalea bellicosa* Deunff, p. 42, pl. 1, fig. 13.
1961 *Cymatiogalea pudica* Deunff, p. 42, pl. 1, fig. 4.
1964 *Cymatiogalea bellicosa* (Deunff); Deunff, p. 122, pl. 1, figs. 10–12, 16, 19–20.

Description. Body spherical to hemispherical in outline, usually with a circular opening and accompanied by a collar. Body wall thick, finely striate. Processes hollow, thick cylindrical in shape, connected by thick membranes. These are situated mainly at the pole opposite to the opening. Margin of the opening is not decorated; distal ends of the processes may be simple or furcated. Clusters are occasionally recorded.

Dimensions. Body diameter: 28–49 μ; length of processes and membranes: 17–36% of body diameter; number of processes: 18–35; thickness of processes: 2–2·5 μ.

Remarks. Deunff (1961) erected *C. pudica* to include forms with membranous structure supported by pillar-like processes developed opposite to the opening. He also described *C. bellicosa* as forms with membranous structures having crests as high as 10 μ usually developed opposite to the polar opening. However, Deunff's photographs of *C. bellicosa* rather reveal the presence of pillar-like thick processes supporting the membranes. In 1964, Deunff again redescribed *C. bellicosa* having membranous structure supported by processes and used *C. pudica* as a synonym of *C. bellicosa*. *C. bellicosa* can be distinguished from *C. membranispina* by its fewer, thicker, and cylindrical processes and lack of decoration at the margin of the opening.

Occurrence. The Tremadoc of England and also the Sahara (Deunff 1961, 1964).

Cymatiogalea cuvillieri (Deunff 1961)

Plate 5, figs. 1 and 2; Plate 7, fig. 2

1961 *Priscogalea cuvillieri* Deunff, p. 41, pl. 1, fig. 2.
1961 *Priscogalea collumellifera* Deunff, p. 41, pl. 1, fig. 3.
1964 *Cymatiogalea cuvillieri* (Deunff); Deunff, p. 124, pl. 1, fig. 2.
1964 *Cymatiogalea collumellifera* (Deunff); Deunff, p. 120.
1967 *Cymatiogalea* cf. *cuvillieri* Deunff; Combaz, pl. III, fig. 82.
1967 *Cyst* of *Cymatiogalea*; Combaz, pl. III, figs. 83 and 84.
1967 *Priscogalea* cf. *cuvillieri* Deunff; Vanguestaine, pl. ii, figs. 18, 19.

Description. Body spherical to hemispherical in outline; wall smooth, divided into polygonal areas by linear arrangement of granules, very short spines, with or without connection by low sutural ridges. Opening is usually circular, but polygonal to subpolygonal openings are also occasionally observed. Spines are very short, 1–2 μ in length. All gradations exist between granules to short processes. Clusters are recorded.

Tabulations: ,1:5:3:0, usually common (about 40%); ,1:5:4:0 (20%); ,1:5:4:1 (10%); ,1:5:5:0 (10%); ,1:4:3:0 (10%); and , 1:4:2:0 (10½%).

Dimensions. Body diameter: 23–37 μ; size of opening: 34–91% of body diameter; size of operculum: 16–24 μ; body wall thickness: 0·5–2 μ; length of processes: 1·5–11% of body diameter.

Remarks. Deunff (1961) recorded the size range of *C. cuvillieri* varying from 20 to 25 μ; with processes about 1 μ high. He described another species *Priscogalea collumellifera* with a test size of 37 μ and short processes up to 3 μ high and somewhat columnar. The present author recorded a wider size range of body as well as very short processes in *C. cuvillieri.* As a result, the present author thinks that *P. collumellifera* is a synonym of *C. cuvillieri.*

Occurrence. The Tremadoc of England and also the Sahara (Deunff 1961, 1964; Combaz 1967); below the base of Salmian (Tremadoc in part) in Belgium (Vanguestaine 1967).

Cymatiogalea multarea (Deunff 1961)

Plate 4, fig. 7; Plate 7, fig. 6; text-fig. 4

1961 *Priscogalea multarea* Deunff, p. 41, pl. 1, fig. 5.
1961 *Priscogalea multiclaustra* Deunff, p. 41, pl. 2, fig. 4.
1964 *Cymatiogalea multarea* (Deunff); Deunff, p. 120.
1964 *Cymatiogalea multiclaustra* (Deunff); Deunff, pl. 1, fig. 6.
1967 *Cymatiogalea multarea* (Deunff), Combaz, pl. III, figs. 78, 79, 80, and 81.
1967 *Cymatiogalea multiclaustra* (Deunff); Combaz, pl. III, fig. 85.

Description. Body spherical to hemispherical in outline, body wall smooth to striate divided into polygonal fields by low sutural ridges; processes are simple and slender. Opening is usually circular, occasionally polygonal. Margin of the opening is decorated.

EXPLANATION OF PLATE 5

All figures approximately ×1000 unless otherwise stated.

Figs. 1 and 2. *Cymatiogalea cuvillieri* (Deunff). 1, cluster of several specimens. 2, specimen in hemispherical view. Figs. 3 and 4. *Cymatiogalea cristata* (Downie) comb. nov. 3, specimen in hemispherical view. 4, clusters showing several specimens. ×650 approx. Fig. 5. Isolated polygonal operculum probably of *Cymatiogalea cristata* nov. comb. Fig. 6. *Cymatiogalea* cf. *stelligera* Górka. Fig. 7. *Cymatiogalea trifida* sp. nov., holotype. Fig. 8. Isolated round operculum probably of *Cymatiogalea multarea* (Deunff). Fig. 9. *Cymatiogalea membrana* sp. nov., holotype.

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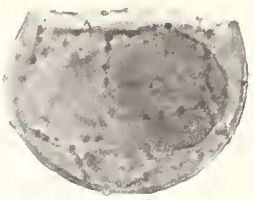

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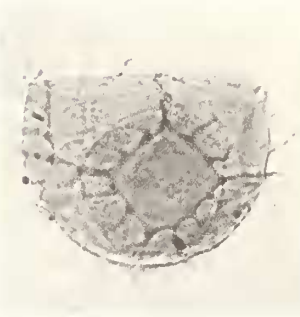

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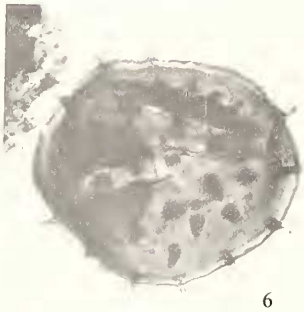

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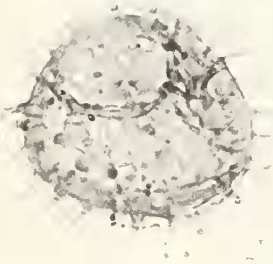

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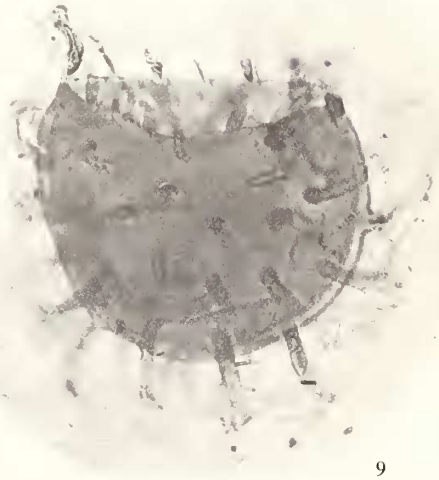

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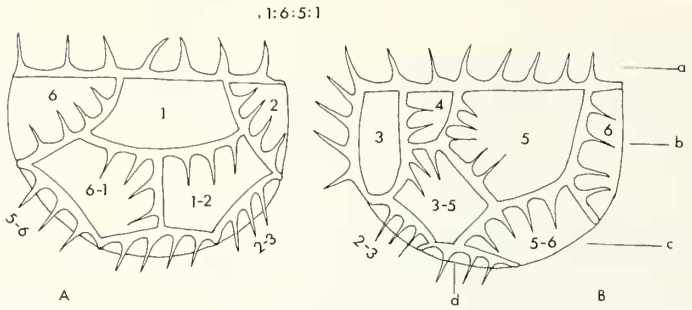
RASUL, Tremadocian acritarchs



TEXT-FIG. 4. Tabulation pattern in *Cymatiogalea multarea* Deunff 1964; Hemispherical view (×1000 approx.). A, top surface. B, low surface. *a*, first row. *b*, second row. *c*, third row. *d*, basal row.

Tabulations: ,1:6:6:0, usually common (about 50%). Other types: ,1:6:5:0 (20%); ,1:6:5:1 (10%); ,1:5:5:1 (10%); ,1:5:1:0 (10%).

Dimensions. Body diameter: 30–42 μ; thickness of body wall: 0·5–2·8 μ; length of processes: 11–25% of body diameter.

Remarks. Deunff recorded *C. multarea* having a body diameter of 36 μ; polar aperture about 27 μ, and slender processes about 10 μ high. He also erected *C. multiclaustra* possessing a body diameter of 40 μ, polygonal opening about 15 μ, and more or less sinuous processes about 8 to 10 μ high. Since the size range of the opening in a particular species is highly variable according to the polar or hemispherical preservations of the specimens and that the same species may possess either circular or polygonal opening, the present author thinks that *C. multiclaustra* is a synonym of *C. multarea*. *C. multarea* differs from *C. cuvillieri* in possessing larger processes.

Occurrence. The Tremadoc of England and also the Sahara (Deunff 1961, 1964; Combaz 1967).

Cymatiogalea cristata (Downie 1968) comb. nov.

Plate 5, figs. 3 and 4; Plate 7, fig. 1; text-fig. 5

1958 *Baltisphaeridium cristatum* Downie, p. 338, pl. 16, fig. 4.
1958*b* *Baltisphaeridium cristatum* (Downie); Eisenack, p. 400.
non 1962 *Baltisphaeridium cristatum* (Downie); Eisenack, p. 360, tab. 44, fig. 9.
1967 *Cymatiogalea polygonophora* Górka, p. 3, pl. 1, figs. 5–6.
1968 *Priscogalea cristata* (Downie); Martin, p. 85, pl. 1, figs. 43, 44, and 46.
1968 *Cymatiogalea polygonophora* (Górka); Górka, pl. XVI, fig. 10, text-fig. 24.

EXPLANATION OF PLATE 6

All figures approximately ×1000 unless otherwise stated.

Figs. 1–5. *Cymatiogalea cylindrata* sp. nov. 1, specimen showing most of the processes in focus. 2, *Forma 1*, holotype. 3, *Forma 2*, showing acicular processes. 4, steroscan figure. ×2000 approx. 5, specimen showing presence of a thin partial flange in between the process. Figs. 6 and 7. *Cymatiogalea diversita* sp. nov. 6, specimen showing sutural split. 7, holotype.

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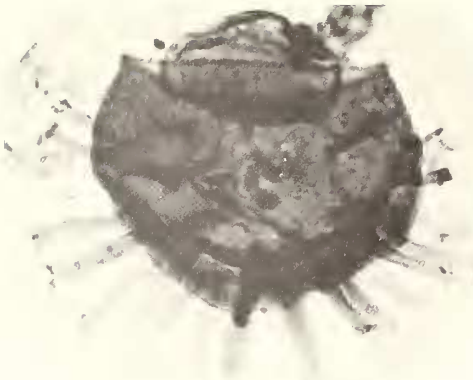

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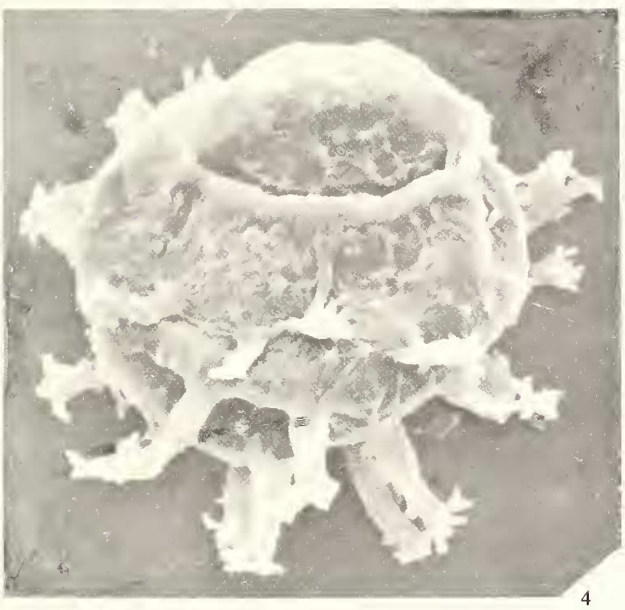

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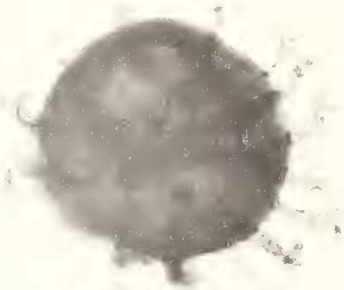

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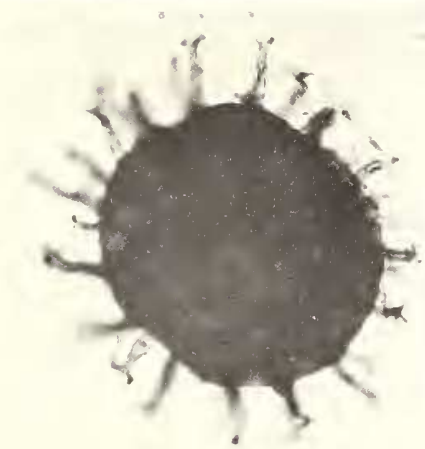

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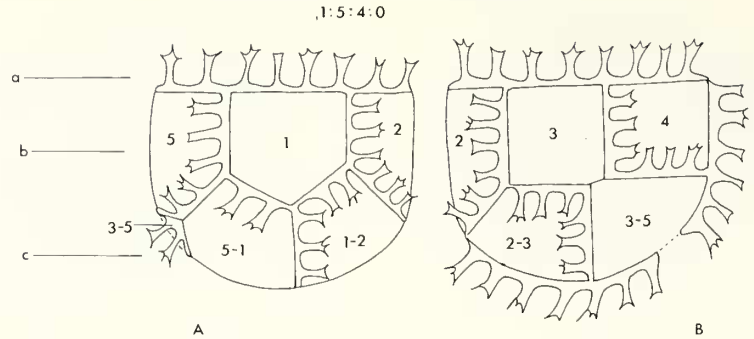
RASUL, Tremadocian acritarchs



TEXT-FIG. 5. Tabulation pattern in *Cymatiogalea cristata* nov. comb; Hemispherical view (×1000 approx.). A, top surface. B, low surface. *a*, first row. *b*, second row. *c*, third row.

Description. Body spherical to hemispherical in outline; wall granular, usually divided into polygonal areas by low sutural ridges. Opening subpolygonal to round, margin decorated. Processes branch distally into two to four spines from a common point near the tips. Clusters recorded.

Tabulation: ,1:5:4:0 (30%); ,1:5:2:0 (30%); ,1:5:3:0 (20%); ,1:5:5:1 (10%); ,1:4:1:0 (5%); ,1:6:6:4 (5%).

Dimensions. Body diameter: 23–36 μ; size of opening: 52–91% of the body diameter; size of operculum: 14–19 μ; length of processes: 12–30% of body diameter; test wall: 1–2 μ thick.

Remarks. C. multarea differs from *C. cristata* in possessing simple processes. *Baltisphaeridium cristatum* recorded by Eisenack from the Arenigian of Estonia is not similar to *C. cristata*, since it possesses quite different polygonal fields of the test wall and numerous processes.

Occurrence. The Tremadoc of England and also Poland (Górka 1967, 1969) and Belgium (Martin 1968).

Cymatiogalea membrana sp nov.

Plate 5, fig. 9

Holotype. Slide S6/1; ref. 3471253. Bullhill Brook, Evenwood, Shropshire; Shumardia Pusilla Zone.

Diagnosis. Spherical to hemispherical body having larger, thick processes of Baltisphaerid type, with strong veils stretching out between the processes. The bases of the processes are thickened, the tips furcated; opening circular to subpolygonal. Margin of the opening decorated by processes and membranes. The processes follow rather a linear arrangement indirectly producing polygonal areas on the test surface, but the tabulation pattern is difficult to work out; test wall infrareticulate.

Dimensions. Body diameter: 35–45 μ; length of processes and membranes: 24–49% of body diameter; size of opening: 42–30% of body diameter; size of operculum:

20–27 μ; thickness of processes: 1–2·5 μ; holotype: body diameter 43·5 μ; length of processes and membranes: 25% of body diameter; size of opening: 75% body diameter; size of operculum: 23·5 μ.

Remarks. C. membrana which somewhat resembles *C. bellicosa* can be distinguished by its decorated margin of the opening and numerous processes. *C. membrana* differs from *C. membranispina* by its thicker, larger processes having furcated tips.

Cymatiogalea cf. *stelligera* Górka

Plate 5, fig. 6

Description. Spherical to hemispherical body with simple, hollow, tapering processes rarely bifurcated; the bases of the processes are wider, thickened, and truncated with a circular outline. Low ridges six to eight in number radiate from the base of each process and they join others to form a sort of network, similar to those observed in *C. stelligera* Górka; body wall thick, opening is circular.

Dimensions. Body diameter: 34–45 μ; size of opening: 52–85% of body diameter; size of operculum: 17–21 μ; processes: 10–25% of body diameter; no. of processes: about 25–40; body wall: 1·5–3 μ thick; bases of processes: 2–2·5 μ wide.

Remarks. C. cf. *stelligera* can be distinguished from *C. stelligera* by its fewer processes having broad bases. *C. stelligera* possesses numerous closely spaced processes and, as a result, the polygonal areas observed on the body wall are smaller than those present in *C.* cf. *stelligera* Górka.

Cymatiogalea cylindrata sp. nov.

Plate 6, figs. 1–5

Holotype. Slide T2/1; ref. 3421326. Chermes Dingle, Shropshire; Transition Beds.

Diagnosis. Spherical to hemispherical body, usually with a circular polar opening, surrounded by a collar. Processes are hollow, cylindrical in nature with digitate tips; process wall may be smooth, granular, or acicular; body wall thick, microreticulate. Margin of the opening is devoid of processes; thin veils are recorded occasionally to interlink some of the processes.

Dimensions. Body diameter: 28–44 μ; size of opening: 51–91% of body diameter; length of processes: 12–35% of body diameter; no. of processes: 18–40; size of operculum: 17–21·7 μ; thickness of processes: 0·5–2·5 μ; holotype: body diameter 43·5 μ; size of opening: 80% of body diameter; length of processes: 12–28% of body diameter.

Description. On the basis of the nature of processes, two varieties of species can be recognized. *Forma 1.* Forms usually with smooth processes. *Forma 2.* Forms usually with granular to acicular processes. Gradations exist between these two forms.

Remarks. C. cylindrata sp. nov. can be distinguished from *C. membrana* sp. nov. by its nature of processes, lack of thick membranes and marginal decoration of the opening. *C. bellicosa* Deunff differs in possessing membranes supported by processes.

Cymatiogalea trifida sp. nov.

Plate 5, fig. 7

non 1931 *Hystrichosphaeridium trifurcatum* Eisenack, p. 14, figs. 21, 22, and 23.
1958 *Hystrichosphaeridium trifurcatum* Downie, p. 339, text-fig. 4*d*.

Holotype. S1/1; ref. 353118. Shineton Brook, Shineton, Shropshire; Shumardia Pusilla Zone.

Diagnosis. Spherical to hemispherical body having closely spaced processes usually trifurcating near the tips from a common point; body wall granular; the bulbous bases of the processes are joined by fine sutural ridges giving rise to numerous small polygonal areas on the test surface; occasionally a few bifurcated or simple processes may develop.

Dimensions. Body diameter: 25–37 μ; length of processes: 10–20% of body diameter; size of the opening: 46–75% of body diameter; size of operculum: 14–18 μ; holotype: body diameter 30 μ; size of the opening: 46% of body diameter; length of processes: 12–15% body diameter.

Remarks. *C. stelligera* can be distinguished from *C. trifida* by its simple processes and larger size range of the test. *C. cristata* which somewhat resembles *C. trifida* in respect of processes can be distinguished by its fewer processes and tabulation pattern.

Cymatiogalea diversita sp. nov.

Plate 6, figs. 6 and 7

Holotype. Slide B12/1; ref. 1691245. Cressage Brook, Cressage, Shropshire; Brachiopod Beds.

Diagnosis. Spherical to hemispherical body, divided into polygonal fields by linear arrangement of processes, or by faint to prominent sutural ridges. Processes appear closed to the interior of the body, slender, variable in nature; some are simple, some forked near the tips or halfway towards the tips; others are multifurcate. All these variations are present in a single specimen. Body wall thick, microgranular.

Tabulation: ,1:5:4:0 (50%); ,1:4:3:0 (40%); ,1:5:2:0 (10%).

Dimensions. Body diameter: 29–42 μ; size of opening: 59–91% of body diameter; size of operculum: 17–20 μ; length of processes: 11–35% of body diameter; body

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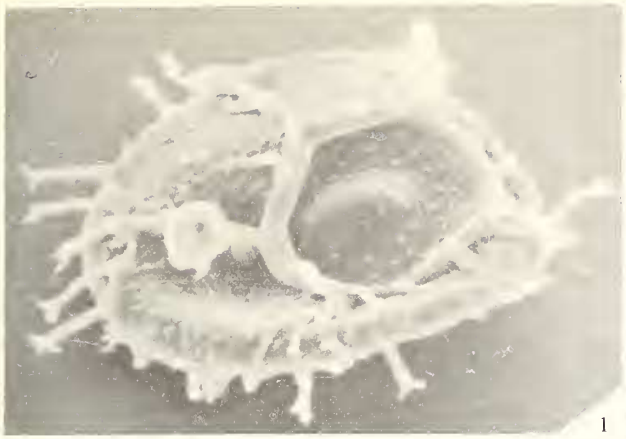
EXPLANATION OF PLATE 7

Stereoscan figures approximately $\times 2000$.

Fig. 1. *Cymatiogalea cristata* (Downie) comb. nov. in polar-lateral view showing wide marginal area of the opening. Fig. 2. *Cymatiogalea cuvillieri* (Deunff) in hemispherical view showing opening with opereulum missing. Fig. 3. *Priscogalea distincta* sp. nov. in hemispherical view showing opereulum loosely attached to the test. Fig. 4. *Priscogalea cortinuala* Deunff in hemispherical view showing operculum folded and loosely attached to the test. Fig. 5. *Cymatiogalea membranispina* Deunff in polar view showing proeesses interlinked by flanges with round outline of the opening in the eentre of the test. Fig. 6. *Cymatiogalea multarea* (Deunff) in hemispherical view.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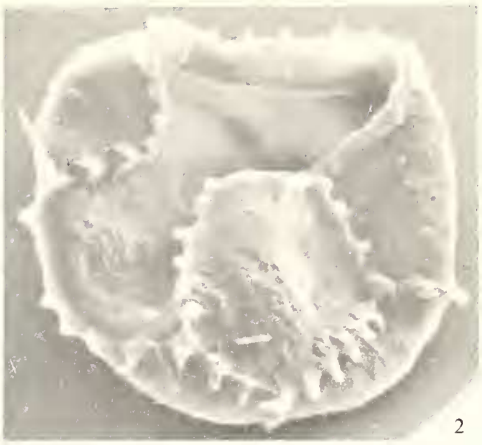
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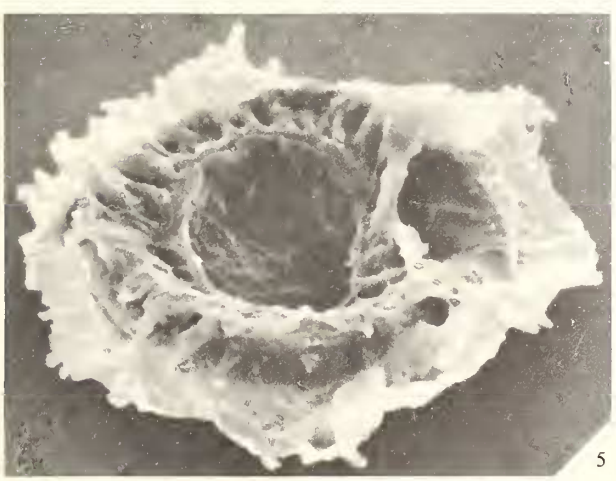
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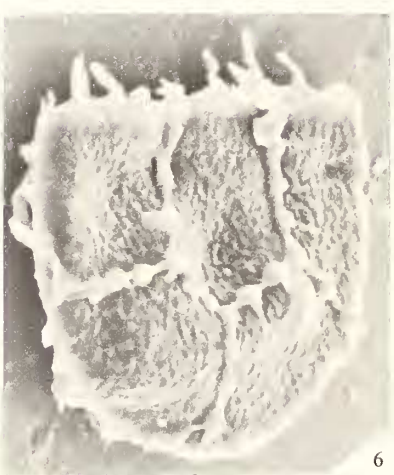
6

RASUL, Tremadocian acritarchs

wall: 0·5–2 μ thick; holotype: body diameter 37 μ (hemispherical position); size of opening: 86% of body diameter; length of processes: 29–32% of body diameter. (Tabulation: , 1:5:2:0.)

Remarks. C. diversita differs from *C. multarea* by its variable nature of processes. *C. cristata* differs in possessing smaller processes which branch distally into 2–4 spines from a common tip.

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